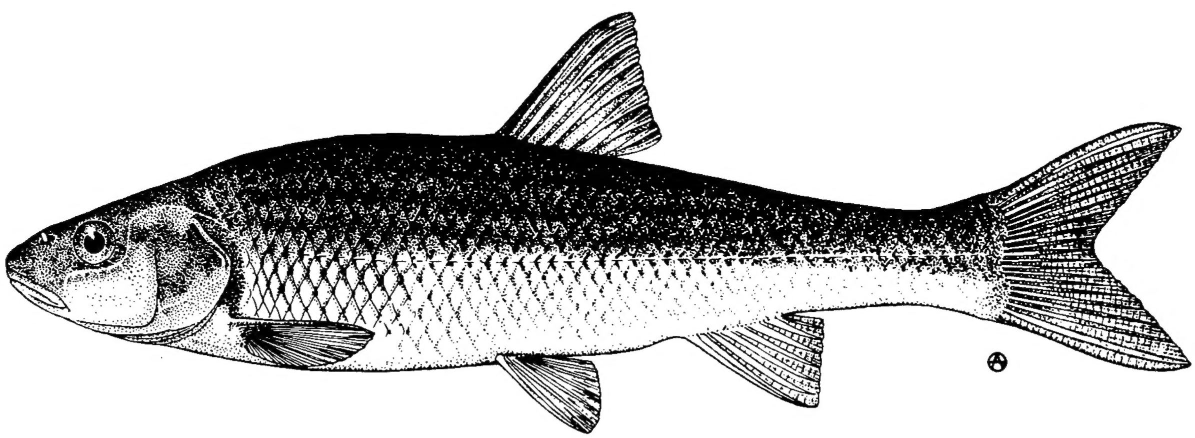
FWS/OBS-82/10.48
SEPTEMBER 1983

HABITAT SUITABILITY INFORMATION: FALLFISH



Fish and Wildlife Service
U.S. Department of the Interior

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

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HABITAT SUITABILITY INFORMATION: FALLFISH

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PREFACE

The habitat use information and Habitat Suitability Index (HSI) models presented in this document are an aid for impact assessment and habitat management activities. Literature concerning a species' habitat requirements and preferences is reviewed and then synthesized into subjective HSI models, which are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into these mathematical models are noted, and guidelines for model application are described. Any models found in the literature which may also be used to calculate an HSI are cited, and simplified HSI models, based on what the authors believe to be the most important habitat characteristics for this species, are presented. Also included is a brief discussion of Suitability Index (SI) curves as used in the Instream Flow Incremental Methodology (IFIM), and a discussion of SI curves available for the IFIM analysis of fallfish habitat.

Use of habitat information presented in this publication for impact assessment requires the setting of clear study objectives. Methods for modifying HSI models and recommended measurement techniques for model variables are presented in Terrell et al. (1982).[1] A discussion of HSI model building techniques is presented in U.S. Fish and Wildlife Service (1981).[2]

The HSI models presented herein are complex hypotheses of species-habitat relationships, not statements of proven cause and effect relationships. Results of model performance tests, when available, are referenced; however, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help us increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send comments to:

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[1]Terrell, J. W., T. E. McMahon, P. D. Inskip, R. F. Raleigh, and K. L. Williamson. 1982. Habitat suitability index models: Appendix A. Guidelines for riverine and lacustrine applications of fish HSI models with the Habitat Evaluation Procedures. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.A. 54 pp.

[2]U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Dept. Int., Fish Wildl. Serv., Div. Ecol. Serv. n.p.

CONTENTS

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FALLFISH (Semotilus corporalis)

HABITAT USE INFORMATION

General

The fallfish (Semotilus corporalis) inhabits rivers, streams, and lakes from the Miramichi drainage in New Brunswick south along the East Coast of the United States to Virginia (Lee et al. 1980). In Canada, fallfish are found in the James Bay region of Quebec and the northern tributaries of the St. Lawrence River and Lake Ontario (Scott and Crossman 1973). In the United States, the Appalachians generally define the western limit of its range. Fallfish also occur in western New York and in a few streams in central Pennsylvania (Lee et al. 1980).

Age, Growth, and Food

The fallfish is a long-lived fish, with an age of XI reported by Reed (1971). Adult size usually varies from 155 to 255 mm (Richardson 1935). Fallfish are one of the few large native North American cyprinids, with a maximum reported length of 508 mm (Shoemaker 1945, cited by Reed 1971). In Quebec, young fish were 35 mm long (Richardson 1935). The sexes grow at similar rates to age IV, after which the growth rate of males exceeds that of females (Reed 1971).

Fallfish are opportunistic feeders; their diet includes aquatic insect larvae, terrestrial insects, crustaceans, and fish (Kingsbury 1977). Algae is also an important constituent of the diet (Reed 1971).

Reproduction

Although some fallfish mature at age II or III, most do not reach maturity until age IV. Males are more likely to be precocious than are females (Reed 1971; Ross in press). In Massachusetts, fecundity was linearly related to length (Fecundity = 14,913 + 76.7 TL) (Richardson 1935). Spawning typically occurs in the spring after water temperatures reach 15° C (Reed 1971). Spawning activity, once initiated, may cease if water temperature drops below 15° C (Ross and Reed 1978). Adams and Hankinson (1928) reported that fallfish spawn in the quiet waters of streams and in the shallow margins of lakes. Our observations in Maine indicate that fallfish move from larger waters into streams to spawn. Fallfish usually construct nests in stream reaches where overhead cover, such as overhanging vegetation or dead brush, or pools occur near areas of suitable spawning substrate (Ross pers. comm.).

Nests in the Mill River near Amherst, MA, were constructed in midstream or at the stream edge at depths of 0.5 m or less (Ross and Reed 1978). Males

move gravel and sand upstream with their mouths and deposit it as a mound, which forms the nest. Each nest is constructed by a single male. A social heirarchy seems to exist, with the nest builder having the highest status and holding a central position on the nest. Spawning is always elicited by the dominant male, normally by dropping a stone on the nest. Three to five females and nearby males rush onto the nest and spawn communally. Twenty or more fallfish may be associated with a single nest (Ross in press). The eggs are adhesive after fertilization (Reed 1971).

Specific Habitat Requirements

Adult. Adult fallfish prefer clear, gravel-bottomed streams and lakes (Scott and Crossman 1973). Larger adults seek pools and deep runs in their riverine habitats. The probability of finding larger individuals increases as the size of the water body increases. Fallfish are commonly found near cascades and falls (Adams and Hankinson 1928). They seldom occur in water over 28° C (Trembley 1960, cited by Scott and Crossman 1973).

Embryo. Embryo incubation usually occurs at temperatures between 16° and 18° C (Reed 1971). Richardson (1935) noted a clearly defined embryo in the egg 2 days after fertilization. Eggs hatched in 138 to 144 hours at 17° C (Reed 1971).

Juvenile. Young fish frequent rapid water more than adults (Scott and Crossman 1973). Our personal observations in Maine indicate that juveniles occur in smaller streams than adults.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The model is applicable throughout the range of the fallfish in North America.

Season. The model assesses the ability of a habitat to support a self-sustaining population of fallfish throughout the year.

Cover types. The model is applicable to freshwater riverine and lacustrine habitats.

Minimum habitat area. Minimum habitat, the minimum amount of contiguous suitable habitat required to sustain a population, has not been determined for fallfish.

Verification level. The fallfish model produces an index between 0 and 1 which is assumed to have a positive relationship to potential habitat carrying capacity. The model has not been verified, but field testing is planned. HSI's calculated from sample data sets appear to be reasonable. These sample data sets are discussed in detail following the presentation of the model.

Model Description - Riverine

The riverine model consists of two components: Water Quality (C_{WQ}) and Reproduction (C_R) (Fig. 1). The variables used to determine habitat suitability are based on very general habitat requirement information. A detailed description of preferred habitat for adult and juvenile fallfish in rivers and streams is not available in the literature.

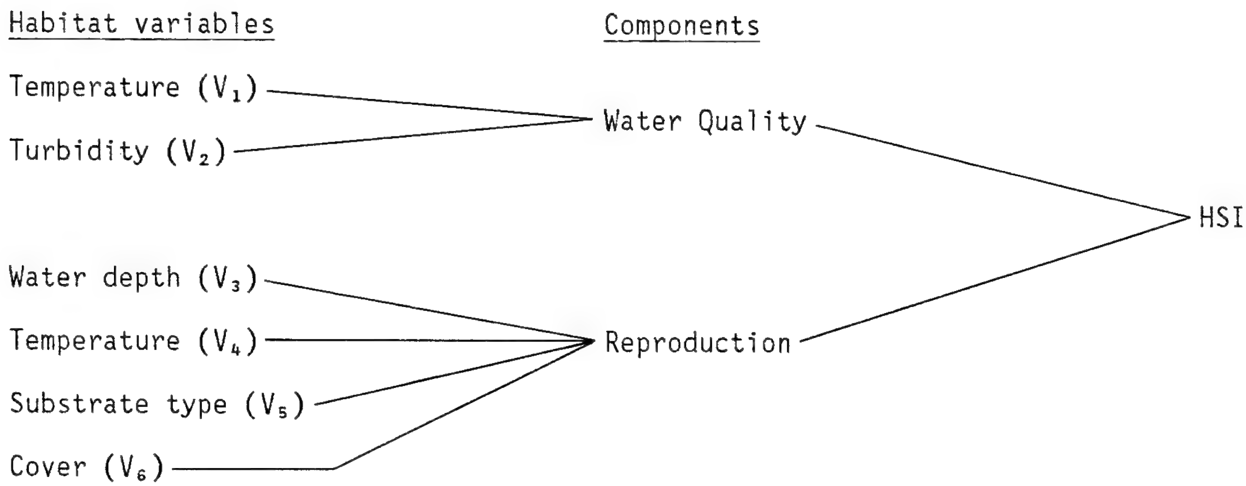


Figure 1. Tree diagram of the variables and components of the riverine model for fallfish.

Water quality component. Temperature (V_1) and turbidity (V_2) are included in the water quality component because fallfish occurrence is apparently limited by these variables. Specific turbidity data were not found in the literature; the assumption was made that "clear" water was < 30 JTU's.

Reproduction component. Water depth (V_3), temperature (V_4), and substrate type (V_5) are included in the reproduction component because they determine the timing and location of successful spawning. Cover (V_6) directly affects the utilization of spawning substrate.

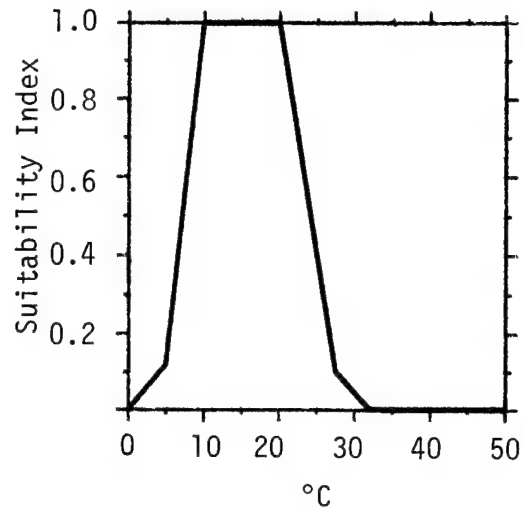
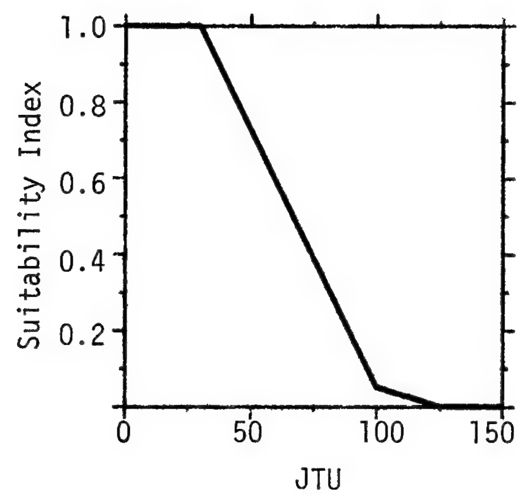
Model Description - Lacustrine

The lacustrine model consists of a single component, water quality (C_{WQ}). Additional habitat model components were not developed due to a lack of available information.

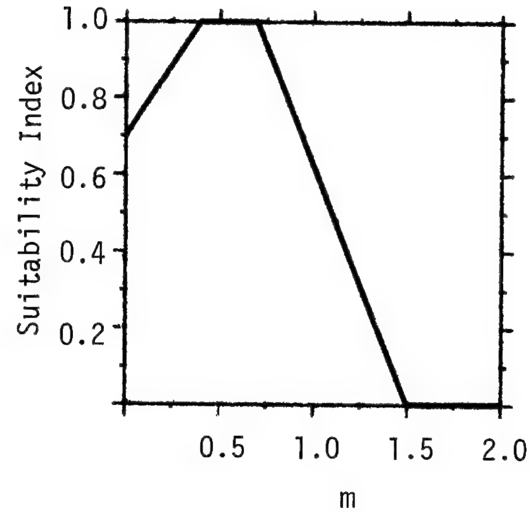
Water quality component. Same assumption as riverine model.

Suitability Index (SI) Graphs for Model Variables

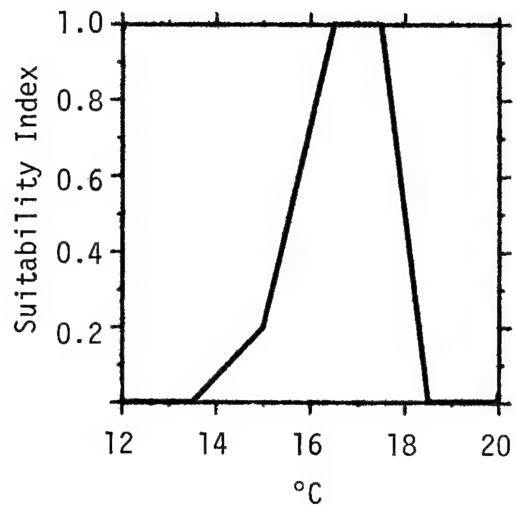
Suitability index graphs for the five variables discussed pertain to riverine (R) or lacustrine (L) habitats, or both.

Habitat	Variable		Suitability graphs
R,L	V_1	Average water temperature during warmest time of year (in lakes - epilimnion; in rivers - main channel).	
R,L	V_2	Average turbidity.	

R V$_3$ Most common water depth measurements (mode) taken at 1/4, 1/2 and 3/4 distance across a stream.

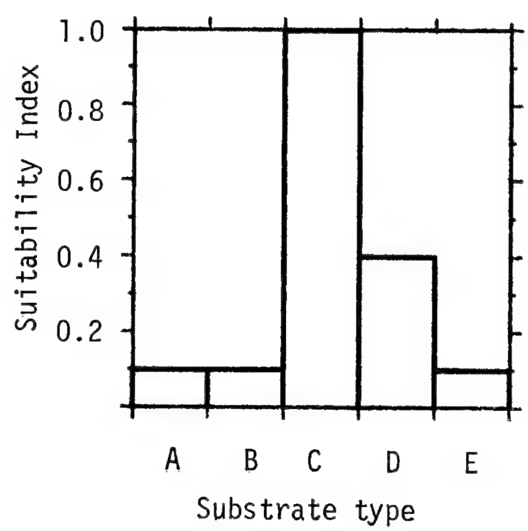


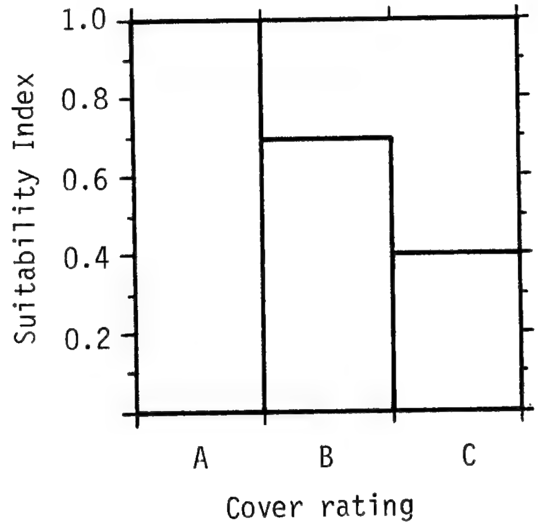
R V$_4$ Temperature throughout the spawning season. (If temperature does not reach the optimum, use the highest temperature reached and sustained for extended periods.)



R V$_5$ Predominant substrate type in streams.

A. Mud, silt, and detritus.
B. Fine sand.
C. Sand and gravel.
D. Rubble.
E. Large rocks and bedrock.



R	V_6	Abundance of instream cover (dead brush and overhanging vegetation, deep pools) near substrate type that is most suitable for spawning. A. High. Occurs in > 60% of specified area. B. Medium. Occurs in 15 to 60% of specified area. C. Scarce or absent. Occurs in < 15% of specified area.	

Riverine Model

The riverine model has water quality and reproduction components.

Water Quality (C_{WQ}).

$$C_{WQ} = (V_1 \times V_2)^{1/2}$$

or, if any value ≤ 0.4, then C_{WQ} = the lowest value of V_1 or V_2.

Reproduction (C_R). If the temperature (V_4) reaches and maintains the optimum value during extended periods in April, May, or June, spawning will occur and the following formula can be used to evaluate reproductive success:

$$C_R = [V_3 \times V_4 \times (V_6 \times V_5)]^{1/3}$$

If V_4 does not reach or maintain the optimum value, then

$$C_R = (V_4) \text{ or } [V_3 \times (V_6 \times V_5)]^{1/2}$$, whichever value is the lowest.

HSI determination. A reach of a stream must have adequate water quality to provide habitat for fallfish. It does not have to contain a spawning area because fallfish will spawn outside of the reach. The model rates an area for both reproduction and water quality. Therefore, it can not be expected to provide an index of actual abundance or to correlate accurately with standing crop, especially when adequate spawning areas exist outside the study reach.

Therefore, $HSI = \frac{C_{WQ} + C_R}{2}$

Lacustrine Model

The lacustrine HSI is based on water quality.

Water Quality (C_{WQ}).

$$C_{WQ} = (V_1 \times V_2)^{1/2}$$

or, if any value ≤ 0.4, then $C_{WQ} = V_1$ or V_2, whichever value is lower.

HSI determination.

$$HSI = C_{WQ}$$

The assumptions used to develop the suitability indices are presented in Table 1. Two hypothetical data sets were used to calculate HSI's for riverine and lacustrine areas (Table 2). The HSI model for streams included all six variables; the HSI model for lakes only included the water quality component (V_1 and V_2 variables). The data sets are not actual field measurements but represent conditions that have been observed in various habitats within the range of the species. The calculated HSI's agree with what the authors believe would be potential carrying capacity trends in streams and lakes with the listed characteristics.

Table 1. Data sources and assumptions for fallfish suitability index graphs.

Variable and source		Assumption
V_1	Scott and Crossman 1973	Fallfish are limited by temperatures greater than 28° C or less than 4° C.
V_2	Scott and Crossman 1973	Preferred level of water clarity is optimum. Water with turbidity less than 30 JTU is considered clear.
V_3	Ross and Reed 1978	Water depths of about 0.5 m are optimum, because most nests occur at this depth.
V_4	Reed 1971	15° C is the minimum temperature for spawning, and 17° C is the optimum. Lowering of temperatures below 15° C interrupts spawning.
V_5	Ross and Reed 1978	The substrate size that corresponds to the sand and gravel used in nests is optimum. Lack of cover reduces the suitability of spawning substrate.
V_6	Ross (pers. comm.)	Because most nests are constructed near cover, abundant cover near preferred substrate is required for optimum habitat.

Table 2. Hypothetical data sets for riverine and lacustrine models.

Variable		Data set 1 Data	Data set 1 SI	Data set 2 Data	Data set 2 SI
Temperature (average)	V_1	25	0.35	15	1.00
Turbidity (JTU)	V_2	60	0.58	40	0.90
Water depth (m)	V_3	0.8	0.85	0.7	1.00
Temperature (spring)	V_4	17	1.00	17	1.00
Substrate	V_5	A	0.10	C	1.00
Instream cover	V_6	A	1.00	A	1.00
Component SI					
C_{WQ}			0.35		0.95
C_R			0.44		1.00
HSI (R)			0.40		0.97
HSI (L)			0.35		0.95

Interpreting Model Outputs

Limited information is available on the habitat requirements of fallfish. Output from the model can be used to classify habitat into two categories: good (HSI ≥ 0.5) or marginal (HSI < 0.5). The precision of the model does not warrant distinguishing other categories of habitat suitability, without more information on fallfish population responses to changing environmental conditions. The quality of spawning habitat can be evaluated using the reproduction component of the model. At this time, the model is largely conceptual. In order to use the model with actual field measurements, the user must carefully define and document how the data were collected and the suitability indices were derived.

ADDITIONAL HABITAT MODELS

No additional habitat models that could be used to determine an HSI for the fallfish were found in the literature.

INSTREAM FLOW INCREMENTAL METHODOLOGY (IFIM)

The U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM), as outlined by Bovee 1982, is a set of ideas used to assess instream flow problems. The Physical Habitat Simulation System (PHABSIM), described by Milhous et al. 1981, is one component of IFIM that can be used by investigators interested in determining the amount of available instream habitat for a fish species as a function of streamflow. The output generated by PHABSIM can be used for several IFIM habitat display and interpretation techniques, including:

1. Optimization. Determination of monthly flows that minimize habitat reductions for species and life stages of interest;

2. Habitat Time Series. Determination of the impact of a project on habitat by imposing project operation curves over historical flow records and integrating the difference between the curves; and

3. Effective Habitat Time Series. Calculation of the habitat requirements of each life stage of a fish species at a given time by using habitat ratios (relative spatial requirements of various life stages).

Suitability Index Graphs as Used in IFIM

PHABSIM utilizes Suitability Index graphs (SI curves) that describe the instream suitability of the habitat variables most closely related to stream hydraulics and channel structure (velocity, depth, substrate, temperature, and cover) for each major life stage of a given fish species (spawning, egg incubation, fry, juvenile, and adult). The specific curves required for a PHABSIM analysis represent the hydraulic-related parameters for which a species or life stage demonstrates a strong preference (i.e., a pelagic species that only shows preferences for velocity and temperature will have very broad curves for

depth, substrate, and cover). Instream Flow Information Papers 11 (Milhous et al. 1981) and 12 (Bovee 1982) should be reviewed carefully before using any curves for a PHABSIM analysis. SI curves used with the IFIM that are generated from empirical microhabitat data are quite similar in appearance to the more generalized literature-based SI curves developed in many HSI models (Armour et al. 1983). These two types of SI curves are interchangeable, in some cases, after conversion to the same units of measurement (English, metric, or codes). SI curve validity is dependent on the quality and quantity of information used to generate the curve. The curves used need to accurately reflect the conditions and assumptions inherent to the model(s) used to aggregate the curve-generated SI values into a measure of habitat suitability. If the necessary curves are unavailable or if available curves are inadequate (i.e., built on different assumptions), a new set of curves should be generated (data collection and analyses techniques for curve generation will be included in a forthcoming Instream Flow Information Paper).

There are several ways to develop SI curves. The method selected depends on the habitat model that will be used and the available database for the species. The validity of the curve is not obvious and, therefore, the method used to generate the curve and the quality of the database are very important. Care also must be taken to choose the habitat model most appropriate for the specific study or evaluation; the choice of models will determine the type of SI curves that will be used. For example, in an HSI model, an SI curve for velocity usually reflects suitability of average channel (stream) velocity (i.e., a macrohabitat descriptor); in an IFIM analysis, SI curves for velocity are assumed to represent suitability of the velocity at the point in the stream occupied by a fish (i.e., a microhabitat descriptor) (Armour et al. 1983).

A system with standard terminology has been developed for classifying SI curve sets and describing the database used to construct the curves in IFIM applications. The classification is not intended to define the quality of the data or the accuracy of the curves. There are four categories in the classification. A literature-based (category one) curve has a generalized description or summary of habitat preferences from the literature as its database. This type of curve usually is based on information in published references on the upper and lower limits of a variable for a species (e.g., juveniles are usually found at water depths of 0.3 to 1.0 m). Unpublished data and expert opinion can also be used to develop these curves. Occasionally, the reference also contains information on the optimum or preferred condition within the limits of tolerance (e.g., juveniles are found at water depths of 0.3 to 1.0 m, but are most common at depths from 0.4 to 0.6 m). Most of the SI curves presently available for use with the IFIM, and virtually all of the SI curves published in the HSI series for depth, velocity, and substrate, are category one curves.

Utilization curves (category two) are based on a frequency analysis of fish observations in the stream environment with the habitat variables measured at each sighting [see Instream Flow Information Paper 3 (Bovee and Cochnauer 1977) and Instream Flow Information Paper 12 (Bovee 1982:173-196)]. These curves are designated as utilization curves because they depict the habitat conditions a fish will use within a specific range of available conditions.

Because of the way the data are collected for utilization curves, the resulting function represents the probability of occurrence of a particular environmental condition, given the presence of a fish of a particular species, P(E|F). Utilization curves are generally more precise for IFIM applications than literature-based curves because they are based on specific measurements of habitat characteristics where the fish actually occur. However, utilization curves may not be transferable to streams that differ substantially in size and complexity from the streams where the data were obtained.

A preference curve (category three) is a utilization curve that has been corrected for environmental bias. For example, if 50% of the fish are found in pools over 1.0 m deep, but only 10% of the stream has such pools, the fish are actively selecting that type of habitat. Preference curves approximate the function of the probability of occurrence of a fish, given a set of environmental conditions:

$$P(F|E) \simeq \frac{P(E|F)}{P(E)}$$

Only a limited number of experimental data sets have been compiled into IFIM preference curves. The development of these curves should be the goal of all new curve development efforts.

The fourth category of curves is still largely conceptual. One type of curve under consideration is a cover-conditioned, or season-conditioned, preference curve set. Such a curve set would consist of different depth-velocity preference curves as a function or condition of the type of cover present or the time of year. No fourth category curves have been developed at this time.

The advantage of category three and four curves is the significant improvement in precision and confidence in the curves when applied to streams similar to the streams where the original data were obtained. The degree of increased accuracy and transferability obtainable when applying these curves to dissimilar streams is unknown. In theory, the curves should be widely transferable to any stream in which the environmental conditions are within the range of conditions found in the streams from which the curves were developed.

Availability of Graphs for Use in IFIM

Most of the information available on fallfish refers to spawning and egg incubation (Table 3). Preferences of adults, juveniles, and fry for depth, current velocity, and cover are unknown. Preferences of juveniles and fry for substrate type are unknown. Not enough SI curves are available for an IFIM analysis of fallfish habitat and, therefore, an investigator will have to develop most of the necessary curves before using the PHABSIM model.

Table 3. Availability of curves for IFIM analysis of fallfish habitat.

	Velocity	Depth	Substrate[a]	Temperature[b]	Cover[b]
Spawning	No curve available.	Use SI[c] = 1.0 for depths 0.1-0.5 m (see text, page 2).	Use SI[c] = 1.0 for sand and gravel (see text, page 2).	Use SI curve for V_4.	Use SI curve for V_6.
Egg incubation	No curve available.	Use SI[c] = 1.0 for depths 0.1-0.5 m (see text, page 2).	Use SI[c] = 1.0 for sand and gravel (see text, page 2).	Use SI curve for V_4.	Use SI curve for V_6.
Fry	No curve available.	No curve available.	No curve available.	Use SI curve for V_1.	No curve available.
Juvenile	No curve available.	No curve available.	No curve available.	Use SI curve for V_1.	No curve available.
Adult	No curve available.	No curve available.	Use SI[c] = 1.0 for gravel (see text, page 3).	Use SI curve for V_1.	No curve available.

[a]The following categories may be used for IFIM analyses (see Bovee 1982):

1 = plant detritus/organic material
2 = mud/soft clay
3 = silt (particle size < 0.062 mm)
4 = sand (particle size 0.062-2.000 mm)
5 = gravel (particle size 2.0-64.0 mm)
6 = cobble/rubble (particle size 64.0-250.0 mm)
7 = boulder (particle size 250.0-4000.0 mm)
8 = bedrock (solid rock)

[b]When use of SI curves is prescribed, refer to the appropriate curve in the HSI model section.

[c]Use SI = 1.0 if the habitat variable is optimal; if the habitat variable is less than optimal, the user must determine, by judgement, the most appropriate SI value.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop riverine and lacustrine habitat models for Fallfish (Semotilus corporalis) a freshwater species. The models are scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for freshwater, marine and estuarine areas of the continental United States. Habitat Suitability indexes (HSI's) are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

Also included are discussions of Suitability Index (SI) curves as used in the Instream Flow Incremental Methodology (IFIM) and SI curves available for an IFIM analysis of Fallfish habitat.

17. Document Analysis a. Descriptors
Mathematical models
Fishes
Aquatic biology
Habitability

b. Identifiers/Open-Ended Terms
Fallfish
Semotilus corporalis
Habitat Suitability Index
Instream Flow Incremental Methodology

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	15
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(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

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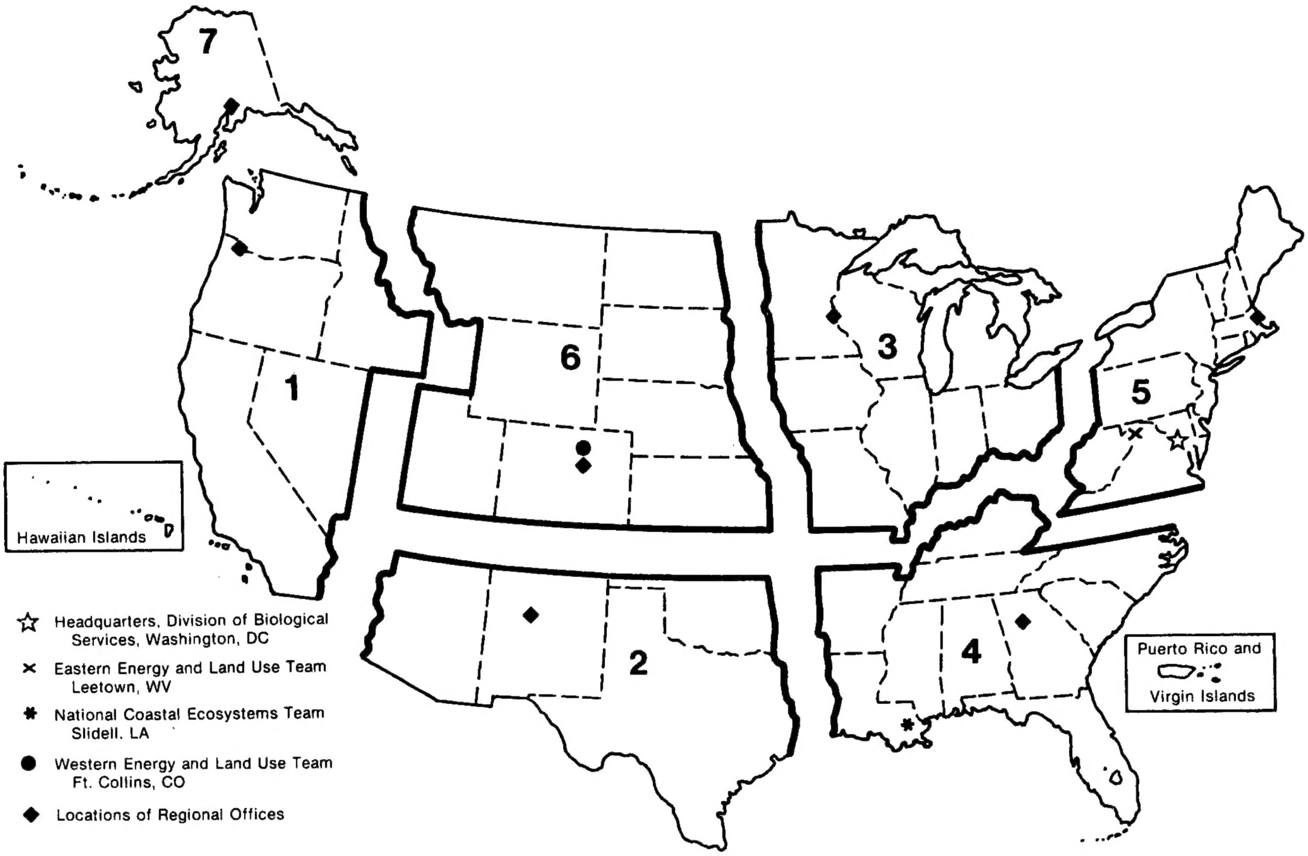

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